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LATEST CHORUS AND NOMAD RESULTS

K. Zuber
Department of Physics, University of Oxford, Keble Road,
Oxford OX1 3RH, England

The final result of the NOMAD searches on ν_μ - ν_τ oscillations as well as the current status of CHORUS are described. The $\nu_\mu - \nu_e$ analysis of NOMAD excludes the parameter region of LSND in the range $\Delta m^2 > 10$ eV^2 . New results on charm physics from both experiments are presented.

1 Introduction

A non-vanishing rest mass ot the neutrino has far reaching consequences from cosmology down to particle physics. For a recent review see [1]. In the last years growing evidence for such a mass arose in neutrino oscillation experiments . In a simple two flavour mixing scheme the oscillation probability P is given by

$$P(L/E_\nu) = \sin^2 2\theta \sin^2(1.27\Delta m^2{}_{ij} L/E_\nu) \qquad (1)$$

with $\Delta m^2_{ij} = \mid m_j^2 - m_i^2 \mid$, θ as the mixing angle, L the source-detector distance and E_ν the neutrino energy. Short baseline experiments with high energy neutrino beams offer the chance to probe small mixing angles at rather larger Δm^2 ($\Delta m^2 > 1$ eV^2). It was the intension of CHORUS and NOMAD to probe $\sin^2 2\theta$ almost down to about 10^{-4} for $\nu_\mu - \nu_\tau$ oscillations in that region. High statistics νN scattering allows also for various other kinds of studies, among them charm physics.

2 The experiments

Both experiments were performed in the West Area Neutrino Facility (WANF) at CERN during the years 1994-1998. The beam was an almost pure ν_μ beam with small contaminations of $\bar{\nu}_\mu$ (≈ 6 %) and ν_e (≈ 1 %). The active target of CHORUS consisted of nuclear emulsions

with a total mass of 770 kg [2]. For timing purposes and for extrapolating the tracks back into the emulsions, a scintillating fibre tracker was interleaved. Behind the target complex followed a hexagonal spectrometer magnet for momentum measurement, a high resolution spaghetti calorimeter for measuring hadronic showers and a muon spectrometer. The scanning of the emulsions is performed with high-speed CCD microscopes.
NOMAD was using drift chambers as target and tracking medium [3]. In total there were 44 chambers located in a 0.4 T magnetic field with a fiducial mass of 2.7 tons. They were followed by a transition radiation detector (TRD) for e/π separation, further electron identification devices in form of a preshower detector and an electromagnetic lead glass calorimeter. A hadronic calorimeter and a set of 10 drift chambers for muon identification followed. In front of the drift chambers another iron-scintillator calorimeter of about 20 t target mass was installed.

3 $\nu_\mu - \nu_\tau$ and $\nu_e - \nu_\tau$ analysis

The analysis obtained by CHORUS is based on the search of a kink, coming from the decay of the τ-lepton. The data set are divided in 1μ and 0μ samples based on the possible observation of a muon in the spectrometer. To reduce the load for scanning, further cuts on momentum and angles with respect to the beam are applied. The event finding proceeds in three steps: a vertex location in the emulsion, the search for the decay kink and at the end an eye-scan of candidates. The main background arises from charm production. CHORUS observed 0 events in the 1μ (0.1 expected) and 4 events in the 0μ sample (3.3 expected). This can be transformed into an upper limit on the oscillation probability of P($\nu_\mu - \nu_\tau$) $< 3.4 \cdot 10^{-4}$ (90 % CL) [4]. With a new, more effective scanning method the analysis will be repeated.
NOMAD is not able to observe the τ-lepton directly but relies on the decay kinematics. The variables of use here are basically imbalance and isolation. To obtain maximum sensitivity for an oscillation signal all degree of freedoms of the kinematics and their correlations have to be exploited. In this way the $\tau \to e$ and $\tau \to h(n\pi^0), 3h(n\pi^0)$ decay modes were explored, separated in a low multiplicity and deep inelastic sample. A maximum likelihood method was used together with a blind-box analysis. The box itself is split into bins, where most of the sensitivity is related to low background bins. In these bins $1.60^{+1.69}_{-.39}$ background events were expected and 1 event was observed. The final result from the analysis is a limit of P($\nu_\mu - \nu_\tau$) $< 1.68 \cdot 10^{-4}$ (90 % CL) [5].
Both experiments took advantage of the fact, that there is a 1% beam contamination of ν_e. Correcting for the higher average energy of the ν_e component and modified acceptances, they were able to give limits also on $\nu_e - \nu_\tau$ oscillation probabilities as P($\nu_e - \nu_\tau$) $< 2.6 \cdot 10^{-2}$ (CHORUS) and P($\nu_e - \nu_\tau$) $< 1.68 \cdot 10^{-2}$ (NOMAD) respectively. The current status is shown in Fig. 1.

4 $\nu_\mu - \nu_e$ analysis

A $\nu_\mu - \nu_e$ signal would manifest itself in NOMAD as an increase of ν_e CC events. The difference in the energy and radial distributions of incident ν_e and ν_μ lead to an enhancement of ν_e CC events at low ν_e energies and small radii with respect to the beam axis. To reduce systematic effects the ratio $R_{e\mu}$ defined as

$$R_{e\mu} = \frac{''\nu_e CC''}{''\nu_\mu CC''}(E_\nu, r) = \frac{e^-(\nu_e CC) + e^-(bkg) + e^-(\nu_e{}^{osc} CC)}{\mu^-(\nu_\mu CC) + \mu^-(bkg)}(E_\nu, r) \quad (2)$$

is investigated. The sensitivity can be enhanced to explore $R_{e\mu}$ as a function of neutrino energy E_ν and the radial position of the neutrino interaction vertex r. The analysis is also based on

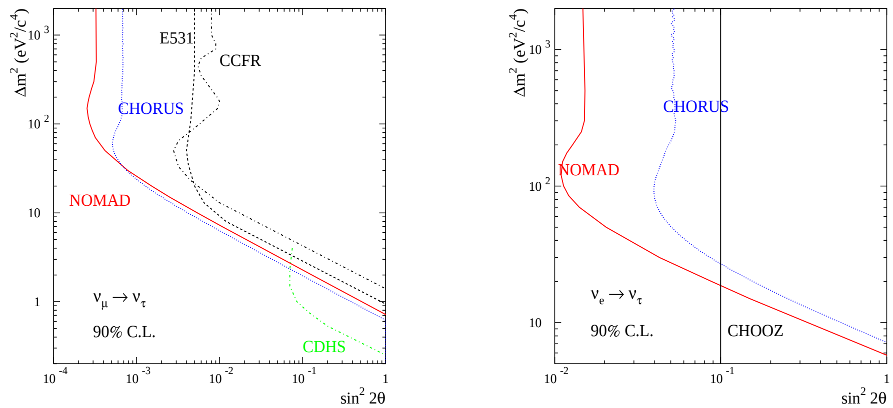

Figure 1: Current status of $\nu_\mu - \nu_\tau$ (left) and $\nu_e - \nu_\tau$ (right) oscillation searches obtained by CHORUS and NOMAD . Superimposed are results from other experiments

kinematical criteria and performed as a "blind" analysis. The crucial part and main uncertainty is a robust prediction of the neutrino flux and energy spectrum. No oscillations were observed [6] resulting in a value of $\Delta m^2 > 0.4$ eV^2 for maximal mixing and $\sin^2 2\theta < 1.2 \cdot 10^{-3}$ for large Δm^2. NOMAD excludes the LSND evidence[7] for $\Delta m^2 > 10$ eV^2 . The $R_{e\mu}$ ratio and the resulting exclusion plot are shown in Fig. 2.

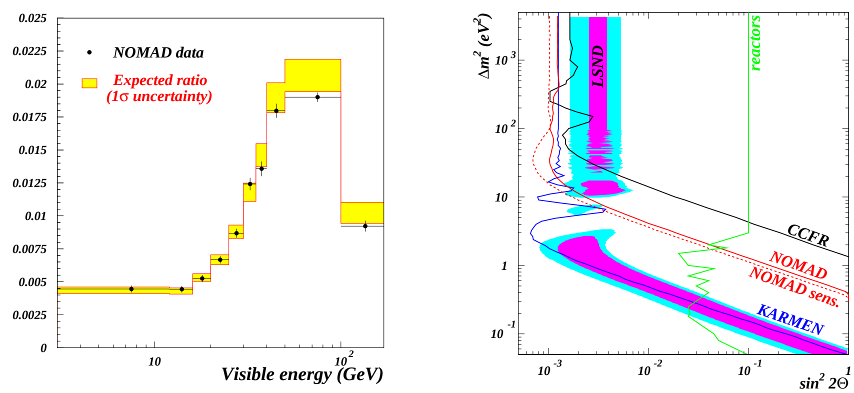

Figure 2: Left: $R_{e\mu}$ as a function of visible energy. The points show the NOMAD data, the histogram corresponds to the expected Monte Carlo predictions assuming no oscillations and 1σ systematic errors added in quadrature. Right: 90 % CL exclusion region in the Δm^2 - $\sin^2 2\theta$ plot and the sensitivity of the NOMAD analysis superimposed on the results of other experiments. A new KARMEN analysis[8] and a combined LSND-KARMEN analysis[9] exist.

5 Charm physics

Charm can be produced via charged current interactions on d- and s-quarks in the nucleon, therefore allowing to explore their structure functions in the nucleon, especially s(x). The charm fragmention can be explored by measuring the various charmed mesons in the final state. From the ratio of opposite sign dimuons versus single muon production as a function of E_ν , m_c can be determined from the threshold behaviour. Such an analysis[10] was performed by NOMAD using 15 % of the data set (Fig. 3). Recently CHORUS performed a search for D^0 production [11]. In total 283 candidates are observed, with an expected background of 9.2 events coming from K and Λ decay. The ratio $\sigma(\mathrm{D}^0)/\sigma(\nu_\mu CC)$ is found to be $(1.99 \pm 0.13(stat.) \pm 0.17(syst.)) \cdot 10^{-2}$ at 27 GeV average ν_μ energy (Fig. 3). NOMAD performed a search for D^{*+} -production using the decay chain D$^{*+} \rightarrow$ D$^0 + \pi^+$ followed by D$^0 \rightarrow K^- + \pi^+$. In total 35 $\pm$ 7.2 events could be

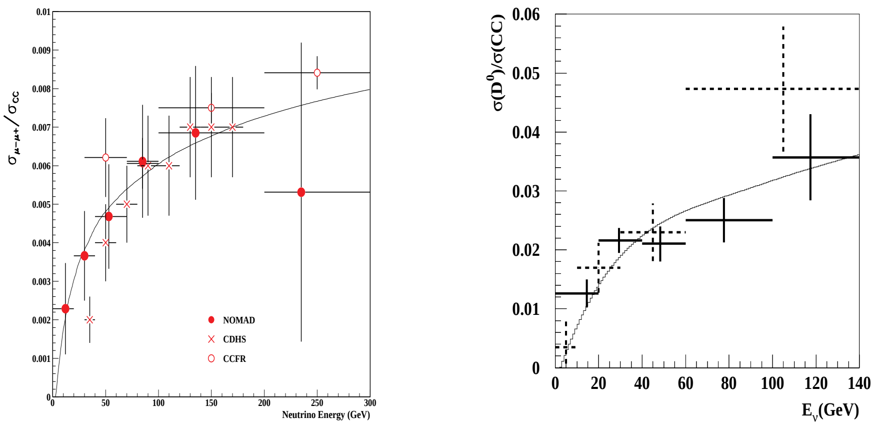

Figure 3: Left: $\sigma(\mu^+\mu^-)/\sigma(\nu_\mu CC)$ as a function of E_ν for a charm quark mass of $m_c = 1.3GeV/c^2$. Also shown are the CCFR (open circles) and CDHS data (crosses). The theoretical curve is using the slow rescaling model in LO QCD, a charm quark mass of $m_c = 1.3GeV/c^2$, a strange quark suppression of $\kappa = 0.48$, an average semileptonic branching ratio of 0.095 and the validity of the CCFR structure functions. Right: D^0 production rate as a function of E_ν as obtained by CHORUS . The result of this analysis are shown as solid lines and compared with those of the E531 experiment, scaled appropriately (dashed lines). The curve shows a fit based on the slow rescaling model to NOMAD charm data multiplied by the (D^0 /charm) cross-section ratio measured.

observed resulting in a D^{*+} yield in ν_μ CC interactions of (0.79±0.17(stat.)±0.10(syst.)) %[12].

6 Summary

Both recent short baseline experiments at CERN, CHORUS and NOMAD , boosted the limit on the mixing angle $\sin^2 2\theta$ for $\Delta m^2 > 10$ eV^2 by an order of magnitude and more with respect to former experiments. The improvement was obtained in the $\nu_\mu - \nu_\tau$ and $\nu_e - \nu_\tau$ channel as well. A recent NOMAD analysis in the $\nu_\mu - \nu_e$ channel can exclude the parameters of the LSND evidence for $\Delta m^2 > 10$ eV^2 . Several interesting results on charm physics were already obtained and can be expected in the future.

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